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GNEP # Material Transportation, Storage & Disposal Analysis FY-07 Summary Report

W. Halsey, R. Wigeland, M. Nutt, T. Bauer, J. D. Smith, K. Sorensen, M. Greiner, M. West

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Global Nuclear Energy Partnership
Advanced Fuel Cycle R&D – Systems Analysis

GNEP – Material Transportation, Storage & Disposal Analysis

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GNEP – Material Transportation, Storage & Disposal Analysis
FY-07 Summary Report

Objective:
Implementation of advanced fuel cycle technology in GNEP brings new requirements for nuclear material transportation, storage and waste disposal. This work addresses the analysis of these requirements and analyzes potential solutions, both near term in support of programmatic documents and decisions, and long term in support of commercial deployment. AFC R&D Material Transportation, Storage and Disposal participants at LLNL, ANL, SNL and INL provide assessment of how GNEP technology can optimize the future evolution of the fuel cycle, including optimization of waste management. Evaluation of material transportation, storage and repository disposal technical issues provides feedback on criteria and metrics for GNEP, and evaluation of GNEP waste streams provides technical alternatives for future repository optimization. LLNL coordinates this effort that includes repository analysis at ANL waste stream analysis at INL and transportation analysis at SNL. Cooperative evaluation with YMP staff is pursued to provide a mutually agreed technical base. Cooperation with select international programs is supported as directed.

FY-2007 Material Transportation, Storage and Disposal Workscope:

1. Integrated GNEP Materials Management and Material Flow Analysis – Evaluation of product and waste streams from GNEP processes. Evaluation of existing transportation, storage and disposal capabilities to show where solutions readily exist, where they require modification or extension, and any areas that require substantial development.

2. Scenario and Repository Evaluations – Ongoing analyses of fuel cycle scenarios and waste disposal alternatives to address systems issues, respond to both internal optimization needs and external information requests

3. DOE-RW Cooperation/Coordination – The interface between DOE-NE fuel cycle program and DOE-RW waste management program is important to both programs. As opportunity permits, this activity will seek to coordinate analyses between the programs for the benefit of both.

Introduction

FY-2007 marked a major change from the broad technology evaluations of the earlier Advanced Fuel Cycle Initiative to amore ambitious but more focused Advanced Fuel Cycle R&D program under the Global Nuclear Energy Partnership, which was announced part way through FY-2006. The more generic Systems Analysis 'Waste Storage and Disposal' effort evolved into a more comprehensive 'Material Transportation, Storage and Disposal Analysis' effort focused on the proposed facilities and technologies for GNEP development and implementation. The objective of this work is to evaluate near-term material management requirements for initial GNEP facilities and activities, long-term requirements for large-scale GNEP technology deployment, and alternatives and paths forward to meet these needs.

Transition to GNEP Material Transportation, Storage and Disposal (M-TSD) included expansion of the prior team to include LLNL, ANL, INL, and SNL, with related work at Univ. Nevada Reno. The charter of the team was broadened to include packaging, transportation, storage and ultimate disposal of all radioactive material streams. At the same time, the work became more focused on the material streams from the nominal GNEP technologies (UREX+1a processing of LWR fuel and full actinide recycle in fast spectrum reactors with either aqueous or electrochemical processing), as well as the proposed GNEP facilities (Advanced Fuel Cycle Facility, Advanced Burner Reactor, Consolidated Fuel Treatment Center). Activities for the year included:

- Preparation of a GNEP Basis Report: "Integrated Strategy for Nuclear Material Transportation, Storage & Disposal Strategy Under the Global Nuclear Energy Partnership", which also served as the source for a M-TSD section of a "GNEP Deployment Strategy" document. One of several versions of this report is attached as an appendix to this FY-07 Summary.
- Cooperation with a new "Integrated Waste Management Strategy" effort that developed a more extensive strategy document and a waste management baseline report. At the close of FY-07, this IWMS and the Systems M-TSD are being more closely coupled.
- Coordination of analyses began with a newly formed Waste Form Campaign, which will conduct R&D and analysis on disposal forms for GNEP waste streams.
- Reviews were conducted of the AFCF 30% conceptual design, and of draft material for the Programmatic Environmental Impact Statement to assure consistency in material management planning across GNEP project elements.
- International partnerships began under GNEP, including a US-Japan working group on waste management R&D.
- Technical analyses (summarized below) were conducted and reported by:
    - ANL – SNF processing and recycle requirement for repository benefit
    - SNL – Transportation cooling times for burner fuels
    - LLNL – Survey of available packaging
    - UN-R – Thermal modeling and testing of SNF shipping casks

As FY-08 approaches, the M-TSD team will continue to add expertise as needed, integrate with IWMS, and prepare technical bases to support mid-year decisions regarding the programmatic path forward.

Material Transportation Storage and Disposal Analysis Summaries

Several technical analyses conducted during FY-07 are summarized below, with reference to more complete reports (where available).

Summary of FY-07 Repository Benefit Analyses (ANL)

An important long-term objective of GNEP is to provide improvement in the long-term management of radioactive waste. Through fast reactor recycle of actinides, it is possible to generate far less waste, and potentially easier waste to manage, than with the current once-thru fuel cycle. However, the precise extent and value of these benefits are complex and difficult to quantify. At the same time, advanced fuel cycles may create additional product and waste streams that require interim storage or extended storage.

The primary analysis of repository benefits is conducted by ANL, with assessment of the impacts of reduced decay heat on potential repository capacity, and reduced long-lived radionuclides on potential repository isolation performance. The primary report for the year was completed in April 2007 "Status Report on Fast Reactor Recycle and Impact on Geologic Disposal" by R. A. Wigeland (INL) and T.H. Bauer and E.E. Morris (ANL), (GNEP-TIO-FUEL-TR-TE-2007-00027, report number INL/EXT-07-12531 and ANL-AFCI-184). This report evaluates the effects of fast reactor recycle on repository disposal, including both thermal based repository capacity and long-term dose potential.

Fast Reactor Recycle and Impact on Geologic Disposal

Previous work has established the relationship between the processing efficiencies of spent LWR fuel, as represented by spent PWR fuel, and the potential increase in repository utilization for the resulting processing waste. A study[1] was completed to determine a similar relationship for the waste from processing spent fast reactor fuel. The wastes from the combination of LWRs and fast reactors as would be deployed with the GNEP approach were then examined.

The conclusions of that study are:

- The higher transuranic content of fast reactor fuel results in a much lower loading density in the repository for direct disposal of spent fast reactor fuel.
- Processing of the spent fast reactor fuel to remove actinides, cesium, and strontium results in large potential increases in repository drift loading for the process waste. However, unlike the process waste from spent PWR fuel, the disposal of the process waste from fast reactor fuel is still limited by the residual transuranic content of the process waste even at an actinide separation efficiency of 99.9%.
- Disposal of process wastes from both PWRs and fast reactors allows for increases in repository drift loading in total since the disposal of process waste from spent PWR fuel is limited by decay heat at the time of placement (short-lived fission products), while disposal of the process waste from spent fast reactor fuel is limited by the integrated

[1] R.A. Wigeland, T.H. Bauer, E.E. Morris, Status Report on Fast Reactor Recycle and Impact on Geologic Disposal, GNEP-TIO-FUEL-TR-TE-2007-00037.

decay heat from the time of closure to about 3000 years after disposal (residual transuranic content).

- Removal of actinides from the spent fast reactor fuel reduces the peak dose rate associated with the disposal of the process waste, but higher separation efficiencies are required as compared to the processing of spent PWR fuel as a result of the higher actinide content in fast reactor fuel.
- Recycle of the actinides in fast reactors results in greater potential increases in repository drift loading for the process waste as compared to thermal recycle. Thermal recycle also reduces the potential drift loading increase with each recycle, and the reduction is more pronounced if curium is also disposed.

Geologic Repository Design and Disposal: GNEP Spent Fuel Processing-Waste Volume

Previous work has shown that removal of key heat generating elements from spent fuel would allow greater utilization of space in a geologic repository such as Yucca Mountain by factors of 100 or more without increasing the estimated peak dose rate to an exposed individual. However, achieving such utilization increases within a repository storage drift requires the density of the remaining fission products, actinide elements, etc. to be increased by roughly the same factor as the utilization increase, itself. Several alternative drift configurations possible within a designated repository area that could: (1) allow greater volume for waste storage and (2) maintain significant utilization benefit were analyzed[2]. The primary conclusions of that study are:

- In agreement with earlier studies, for every drift layout where key heat generating elements are removed from spent fuel, linear and area loading limits of processed waste streams are orders of magnitude higher than those of directly disposed spent fuel.

- Calculated maximum loading densities (per GWd of generated energy) are consistently higher for the PWR waste streams than for the corresponding fast reactor waste streams. This result reflects the proportionately higher discharge inventory of long-lived heat-generating actinide isotopes in fast reactor compared to PWR spent fuel.

- For configurations that are limited by temperature at the drift wall, peak area loadings can be significantly increased by adding more drifts to the repository plane.

- For configurations that are limited by temperature between drifts, peak loadings will be relatively unaffected by any further increase in drift density. In no case, does adding more storage drifts to the repository plane significantly reduce calculated peak area loading densities. Note also that adding storage drifts to the repository plane always increases available storage volume and proportionately reduces the need for waste volume reduction.

[2] T.H. Bauer and R.A. Wigeland. Geologic Repository Design and Disposal: GNEP Spent Fuel Processing-Waste Volume. Global 2007 Conference, Boise, ID, September 9-13, 2007.

- For a representative range of GNEP-generated waste streams, the increase in repository area space utilization by a factor ~100 can be maintained with such configurations as long as waste stream volume can be reduced from that of the original spent fuel by a factor of ~10.

Summary of FY-07 Material Streams and Disposition (LLNL, INL)

Planned decisions in FY-08 regarding the future path for GNEP will require a wide range of technical supporting information. One portion of this information will be the requirements and potential solutions for management of all radioactive material streams – both products for reuse or storage, and wastes for disposal. LLNL and INL staff worked with the new Integrated Waste Management Strategy task to begin evaluation of these material streams for proposed GNEP technologies.

While the details of the GNEP development and deployment strategy are evolving as the program proceeds, it will be necessary to also develop the infrastructure for transportation, storage, and disposal of materials generated by the new technologies. Material transportation, storage and disposal requirements for moderate scale demonstration systems may be less demanding than for large-scale deployment, but confidence that solutions exist must be available sooner to permit early decisions to proceed. Demonstration solutions could include the use or modification of existing capabilities that may not be optimized at full scale. The demonstration facilities then offer the opportunity for development and demonstration of optimized solutions in support of large-scale deployment. A summary of the transportation, storage and disposal requirements in the current, once-thru fuel cycle and those in the demonstration and deployment phases under GNEP is given in Table 1.

Table 1
GNEP Material Transportation, Storage & Disposal Requirements

Material	Current Plan	Demonstration Phase	Deployment Phase
LWR Spent Fuel	Store at Utilities until DOE accepts, transport to MGR	Store at utilities until DOE accepts, then transport to interim storage facility, engineering scale demonstration facility or MGR	Transport from utility storage; store prior to processing at LWR separations, with cooling as appropriate
TRU	Not Applicable	Transfer to AFCF for recycle fuel	Transport to FRFF for recycle fuel
Irradiated U	Not Applicable	Storage for future disposition decisions including potential recycle or disposal as LLW	Storage for future disposition decisions including potential recycle or disposal as LLW
Cladding Hulls	Not Applicable	Put in optimized form for disposal as either HLW or GTCC	Potential recycle or put into optimized form for disposal as either HLW or GTCC
Gaseous Fission Products (^{3}H, Kr, ^{14}C)	Not Applicable	Disposition options include decay storage, disposal as HLW or GTCC or release	Disposition options include decay storage, disposal as HLW or GTCC
Tc	Not Applicable	Immobilize in accepted waste form for geologic disposal	Immobilize in optimized waste form for geologic disposal
Cs/Sr	Not Applicable	Put in ~300 yr storable form; decay storage or disposal as HLW	Extended decay storage and disposal as LLW, GTCC or HLW, or direct disposal in optimized waste form as HLW
All other fission or activation products	Not Applicable	Immobilize in accepted waste form and store until MGR can receive	Immobilize in optimized waste form and dispose as HLW
“Fresh” Recycle FR Fuel	Not Applicable	Store & transport to ABTR	Store & transport to ABRs
Irradiated Recycle FR Fuel	Not Applicable	At-reactor storage for specified cooling period, transport & store for further cooling at AFCF, then process.	At-reactor storage for specified cooling period, then transport & store for further cooling at AFCF or fast SNF processing plant.
Unirradiated ‘depleted’ U	Store; later put in LLW disposable form and dispose	Storage for future disposition decisions including potential recycle or disposal as LLW	Storage for future disposition decisions including potential recycle or disposal as LLW
Low Level Waste	Transport to LLW facility	Transport to LLW facility	Transport to LLW facility
GTCC Waste	Not Applicable	Put in disposable form, store until GTCC facility is available, then transport for disposal	Put in disposable form, store until GTCC facility is available, then transport for disposal

Further discussion of these issues can be found in Appendix 1 of this report, and in IWMS reports currently in preparation.

Summary of FY-07 Transportation Analyses (SNL)

Initial evaluation of transportation thermal limits for the GNEP actinide recycle reactor fuels has been conducted by M-TSD staff at SNL. The executive summary is included here from a more extensive report: "Fast Reactor Recycle Fuel Thermal Load", B. Cipiti, J. D. Smith, and K. Sorenson, Sandia National Laboratories, draft-in-review, September, 2007.

> **"Executive Summary**
> The proposed use of fast reactors in an advanced nuclear fuel cycle as a way to burn down long-lived transuranic actinides, and thereby reduce the repository impacts of heat load and radiotoxicity from the waste generated in production of electricity, has recently seen a marked resurgence in interest as part of the Global Nuclear Energy Partnership. Fast Reactors (FRs) will require a significant shift in current handling and transportation procedures of nuclear fuel, because the transuranic (TRU) elements constituting FR fuel may be considerably "hotter", both thermally and radioactively, than light water reactor (LWR) fuel. FR fuel may also be recycled multiple times, leading to an evolution in the isotopic composition of the contained TRU material.
>
> A series of calculations was performed to estimate the heat generation rate of fast reactor fuels during transportation both to the reactor as "fresh" fuel and after discharge as "spent" fuel. Core loadings for conversion ratios varying from 0 to 1 in 0.25 step increments were simulated covering initial startup, in which TRU characteristics of LWR discharge material was assumed, through five successive recycles of the TRU produced. The heat loadings were compared to a likely thermal limit of a future prototypical transportation cask to provide an operational perspective. A major conclusion, discussed in greater detail below, is after a five-year "cooling" period, the heat generation of the spent fuel is comparable to that produced by the fuel being loaded into the reactor, and a single cask design will likely accommodate shipments of fast reactor recycle fuel both prior to and following irradiation.
>
> Fuel compositions for FRs with conversion ratios between 0 and 1 have been developed in several earlier studies. The present study used those compositions as a starting point employing the ORIGEN isotope generation and depletion code for all subsequent calculations.
>
> The heat generation rate of the fresh fuel is dependent upon the TRU content. Fuel for a reactor with a conversion ratio of 1 is initially about 14% TRU, while fuel yielding a conversion ratio of 0 is comprise of nearly 100% TRU elements. Since the heat generation of the TRU material is about 61 kW/MT, the heat generation rate of the fuel ranges from about 9 kW/MT to 60 kW/MT. For fuels supporting conversion ratios between about 0.25 and 0.75, the heat generation rate of the fresh fuel does not change dramatically, and between 9 and 15 integral assemblies can be accommodated in a cask with a 25 kW thermal limit. Because the five-year cooled spent fuel has a comparable heat generation rate, the cask will also accommodate 9-15 spent fuel assemblies. Therefore, as a preliminary concept, FR fuel casks should be designed with a "standard" outer container and a few (perhaps three or four) inner "baskets" to hold between 8 and 17 assemblies."

Summary of FY-07 Fuel Cask Thermal Modeling and Testing (UN-R)

Researchers at the University of Nevada – Reno are developing improved thermal models of spent fuel shipping casks, and conducting tests to provide new data to support these models. This work had begun under DOE-RW funding, and has transitioned to GNEP, where future work is planned to extend the models to actinide recycle fuel casks. A mid-year report was delivered, "Thermal Analysis Tools for Nuclear Materials and Spent Fuel Storage and Transport", M. Greiner, University of Nevada – Reno, June, 2007. A brief summary of the work detailed in this report is included here.

> "Spent light water reactor fuel is placed in thick wall casks for dry storage and offsite transport. The fuel is supported within square-cross section basket openings inside the cask containment region. That region is filled with a non-oxidizing cover gas. The casks are designed to provide protection during normal and accident conditions while dissipating heat generated by the fuel to the environment. The fuel cladding constitutes and important containment boundary. Its temperature therefore must not exceed its long duration integrity limit of 400°C during normal conditions or its burst rupture temperature of 750°C during or after a fire. The goal of the Cask Internal Heat Transfer component is to develop and benchmark improved tools to predict the cladding temperature under normal and fire accident conditions.
>
> Finite element thermal models are used to predict cask and fuel temperatures during normal and fire conditions. Until recently, computing resources were not available to accurately represent the complex geometry and/or natural convection/radiation heat transfer of the multiple fuel assemblies inside a cask. The fuel regions were replaced with fictitious solid elements with effective thermal conductivities (ETC). Different ETC are used for different fuel assembly designs. The ETC are developed using models that neglect natural convection and some other heat transfer processes. As a result they conservatively overestimate the cladding temperature during normal transport. This can cause cask operators to under estimate the number and heat generation rate of fuel assemblies that can be safely loaded. This increases the number of casks and shipments that are required, as well as the risk of accidents.
>
> Another shortcoming of using effective thermal conductivities is that they underestimate the peak cladding temperature of fuel within a cask caused by a fire. Under some circumstances, finite element simulations that employ them do not predict the fuel cladding will reach its burst rupture temperature when it really does. More accurate fuel region heat transfer models are needed to help analysts design transport and storage systems that better optimize safety, cost and operational efficiency.
>
> Currently available computer resources allow computational fluid dynamics (CFD) simulations to be performed in two-dimensional cask cross section models that accurately represent the fuel. These models are more complete and general than effective thermal conductivities. In the current work, these models are developed and experimentally benchmarked.

The work of the Cask Internal Heat Transfer research component is being performed by two M.S. students, M. Gudipati and V. Venigalla, two Ph.D. candidates, P. Araya and N. Chalasani, and the Principal Investigator. It is broken into the following topics and subtopics. The students working in each topic is indicated in parentheses, and the work for each is described in the following sections.

1. **Computational Scoping Studies**
    - a. Horizontal transport configuration (P. Araya)
    - b. Vertical storage configuration (N. Chalasani)
2. **Full Cask Cross-Section Simulations**
    - a. Rail package normal transport (M. Gudipati)
    - b. Truck cask
        - i. Normal Transport (V. Venigalla)
        - ii. Fire Conditions (V. Venigalla)
3. **Benchmark Experiments** (N. Chalasani and P. Araya)”

Summary of FY-07 Packaging Analyses (LLNL)

M-TSD staff at LLNL have begun a survey of existing packages for radioactive material storage and transport. There is an extensive range of existing packages, which should be reviewed for applicability and availability for GNEP applications. An initial packaging report is included as Appendix B of this report, “*A Survey of Potentially Useful Packages for Storage, Transportation, and Disposition of Un-irradiated, Irradiated, and Source Materials for the Global Nuclear Energy Partnership (GNEP)*”, M. West, Lawrence Livermore National Laboratory, review draft, September, 2007.

Packaging Survey Summary:

> “The Global Nuclear Energy Partnership (GNEP)[i] will require the use of Type A and Type B packages for the transportation and storage and disposition of nuclear materials and nuclear wastes.[ii] Many packages are currently certified by the Nuclear Regulatory Commission (NRC) under 10 CFR 71, Packaging and Transportation of Nuclear Material, for the transportation of un-irradiated and irradiated nuclear fuel in addition to specific separated fission products such as ^{90}Sr and ^{137}Cs. A number of these packages have been identified using the RAMPAC (Radioactive Material Packaging) Website [http://www.rampac.com/], maintained for EM-60’s (Office of Safety Management and Operations) Packaging Certification Program by the Eagle Research Group for the Department of Energy (DOE).”

<u>Summary of FY-07 Material Transportation, Storage and Disposal Analyses Support to Other Program Activities</u>

Material Transportation, Storage and Disposal staff contributed to other programmatic activities.

Facility Planning Reviews

M-TSD staff participated in a review of the 30% Conceptual Design Review for the Advanced Fuel Cycle Facility. This review focused on proposed product and waste stream compositions, storage/disposal forms, storage and transportation requirements and waste disposal pathways, to assure consistent treatment of M-TSD issues.

M-TSD staff participated in a review of the draft Programmatic Environmental Impact Statement. This review focused on representative product and waste stream compositions, storage/disposal forms, storage and transportation requirements and waste disposal pathways.

Coordination with DOE-RW/YMP

At one time in recent years, there had been significant progress in the cooperation between the DOE-NE AFCI program and the DOE-RW Yucca Mountain Project. This included creation of a joint "Spent Fuel Management Steering Committee" to provide a venue for cooperative analysis of waste management issues for advanced fuel cycles. Activities of the Steering Committee have been on hold following management changes at DOE-RW and focus at RW on preparation of the YMP license application. During FY-07, there has been improved participation by RW staff in the work of M-TSD, IWMS, the Waste Form Campaign, and a new US-Japan GNEP Waste Management working group. Further improvement in the cooperation with DOE-RW is needed, and continues to be pursued.

International Cooperation (LLNL)

In late FY-07, a new Joint US-Japan GNEP Waste Management Working Group has been chartered to develop common R&D objectives and seek opportunities for coordinated research. An initial draft of a joint R&D plan has been started, and will continue into FY-08.

Summary of Material Storage, Transportation and Disposal Analysis for GNEP (LLNL)

Transition to GNEP Material Transportation, Storage and Disposal (M-TSD) included expansion of the prior team to include LLNL, ANL, INL, and SNL, with related work at Univ. Nevada Reno. The charter of the team was broadened to include packaging, transportation, storage and ultimate disposal of all radioactive material streams. At the same time, the work became more focused on the material streams from the nominal GNEP technologies (UREX+1a processing of LWR fuel and full actinide recycle in fast spectrum reactors with either aqueous or electrochemical processing), as well as the proposed GNEP facilities (Advanced Fuel Cycle Facility, Advanced Burner Reactor, Consolidated Fuel Treatment Center). Activities for the year included:

- Preparation of a GNEP Basis Report: "Integrated Strategy for Nuclear Material Transportation, Storage & Disposal Strategy Under the Global Nuclear Energy Partnership", which also served as the source for a M-TSD section of a "GNEP Deployment Strategy" document. One of several versions of this report is attached as an appendix to this FY-07 Summary.

- Cooperation with a new “Integrated Waste Management Strategy” effort that developed a more extensive strategy document and a waste management baseline report. At the close of FY-07, this IWMS and the Systems M-TSD are being more closely coupled.
- Coordination of analyses began with a newly formed Waste Form Campaign, which will conduct R&D and analysis on disposal forms for GNEP waste streams.
- Reviews were conducted of the AFCF 30% conceptual design, and of draft material for the Programmatic Environmental Impact Statement to assure consistency in material management planning across GNEP project elements.
- International partnerships began under GNEP, including a US-Japan working group on waste management R&D.
- Technical analyses (summarized below) were conducted and reported by:
    - ANL – SNF processing and recycle requirement for repository benefit
    - SNL – Transportation cooling times for burner fuels
    - LLNL – Survey of available packaging
    - UN-R – Thermal modeling and testing of SNF shipping casks

As FY-08 approaches, the M-TSD team will continue to add expertise as needed, integrate with IWMS, and prepare technical bases to support mid-year decisions regarding the programmatic path forward.

APPENDIX A

GNEP – Basis Document

Integrated Strategy for Nuclear Material Transportation, Storage & Disposal Strategy Under the Global Nuclear Energy Partnership

Objective:

The purpose of this GNEP Basis Document is to:

1) *Acknowledge the broad range of material transportation, storage and waste disposal issues that must be addressed by GNEP.*
2) *Provide confidence that near-term solutions exist or can be developed at the demonstration facility scale – to support a programmatic decision to proceed.*
3) *Provide confidence that reasonable development paths are available to provide large-scale deployment solutions (if different from the near-term).*

Note - This document is not attempting to solve all the issues – rather to acknowledge the issues and suggest one or more reasonable paths forward.

Introduction

In response to the clear need for future growth in non-fossil energy supply, the US DOE has established the Global Nuclear Energy Partnership (GNEP) as the nuclear energy component of the President's Advanced Energy Initiative. GNEP is designed to address national and international issues of energy security, the environment, and non-proliferation.

For nuclear fission energy to be sustainable at large scale, a closed fuel cycle will ultimately be required. Therefore, GNEP includes the demonstration and deployment of three key technologies that would be used to create the closed fuel cycle shown in Figure 1. They are:

1. LWR spent fuel separations technology – UREX+1A is the reference technology due to its technical maturity.
2. Advanced burner reactor technology – the sodium cooled, oxide fueled fast reactor is the reference technology due to its technical maturity.
3. Fast reactor recycle technology – metal fuel fabrication/pyroprocessing or oxide fuel fabrication/aqueous processing are both possible technologies.

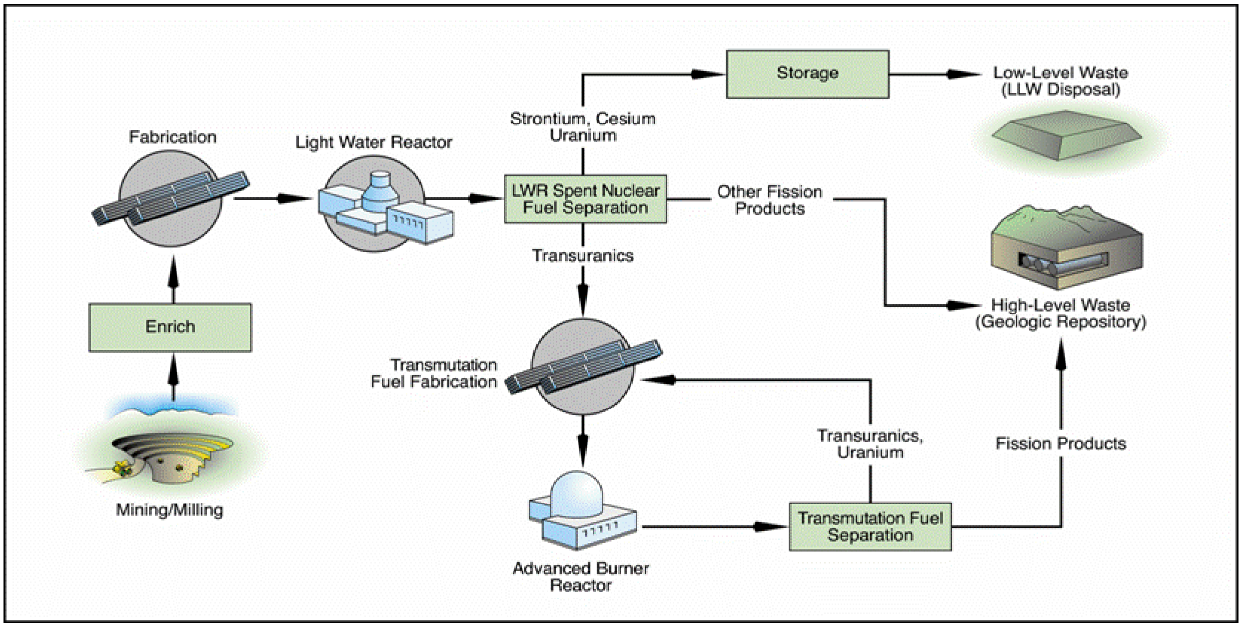

Figure 1. The GNEP Fuel Cycle

Development of these technologies involves a process of research, development and demonstration leading to eventual deployment of commercial facilities. This is accomplished by selecting preferred processes from alternatives and refining the selected processes in progressively larger facilities. It is convenient to divide the time for this progression into an R&D phase, currently underway, a demonstration phase and a deployment phase. (Note that Figure 1 illustrates a fully deployed closed fuel cycle, not the smaller scale demonstration facilities.) Some idea of the timing can be obtained from Figure 2, which shows an example timeline for operation of demonstration and commercial facilities.

In the closed fuel cycle envisioned under GNEP, there are additional nuclear materials and requirements for their storage, transportation and disposal compared to the current US once-thru fuel cycle. These include:

- Delivery of spent LWR fuel to a separations processing facility for partitioning into waste and recycle components – instead of direct delivery to a geologic repository for disposal.
- Interim storage of recycle product material following separation, and subsequent transportation to a fabrication facility for fast reactor fuel.
- Interim storage of a variety of waste streams from LWR separations and, later from fast reactor fuel processing and subsequent transportation to appropriate disposal facilities, with options for extended storage of some streams.
- Interim storage of a variety of waste streams from fast reactor fuel fabrication, and subsequent transportation to appropriate disposal facilities.
- Transportation and interim storage of fresh and used fast reactor fuel.

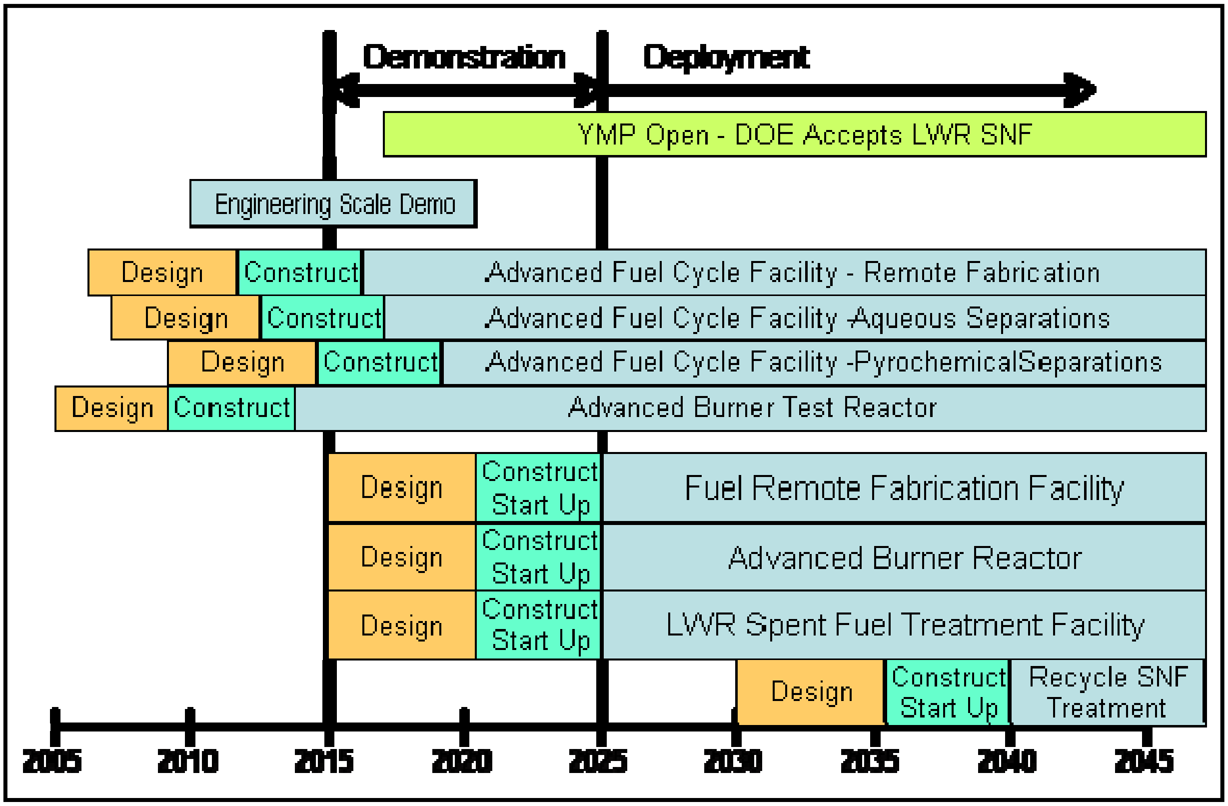

Figure 2. Approximate Timeline for Demonstration and Deployment

While the details of the GNEP development and deployment strategy are evolving as the program proceeds, it will be necessary to also develop the infrastructure for transportation, storage, and disposal of materials generated by the new technologies. Material transportation, storage and disposal requirements for moderate scale demonstration systems may be less demanding than for large-scale deployment, but confidence that solutions exist must be available sooner to permit early decisions to proceed. Demonstration solutions could include the use or modification of existing capabilities that may not be optimized at full scale. The demonstration facilities then offer the opportunity for development and demonstration of optimized solutions in support of large-scale deployment. Because of these differences, this report includes sections on both demonstration and deployment requirements. A summary of the transportation, storage and disposal requirements in the current, once-thru fuel cycle and those in the demonstration and deployment phases under GNEP is given in Table 1.

Table 1
GNEP Material Transportation, Storage & Disposal Requirements

Material	Current Plan	Demonstration Phase	Deployment Phase
LWR Spent Fuel	Store at Utilities until DOE accepts, transport to MGR	Store at utilities until DOE accepts, then transport to interim storage facility, engineering scale demonstration facility or MGR	Transport from utility storage; store prior to processing at LWR separations, with cooling as appropriate
TRU	Not Applicable	Transfer to AFCF for recycle fuel	Transport to FRFF for recycle fuel
Irradiated U	Not Applicable	Storage for future disposition decisions including potential recycle or disposal as LLW	Storage for future disposition decisions including potential recycle or disposal as LLW
Cladding Hulls	Not Applicable	Put in optimized form for disposal as either HLW or GTCC	Potential recycle or put into optimized form for disposal as either HLW or GTCC
Gaseous Fission Products (^3H, Kr, ^{14}C)	Not Applicable	Disposition options include decay storage, disposal as HLW or GTCC or release	Disposition options include decay storage, disposal as HLW or GTCC
Tc	Not Applicable	Immobilize in accepted waste form for geologic disposal	Immobilize in optimized waste form for geologic disposal
Cs/Sr	Not Applicable	Put in ~300 yr storable form; decay storage or disposal as HLW	Extended decay storage and disposal as LLW, GTCC or HLW, or direct disposal in optimized waste form as HLW
All other fission or activation products	Not Applicable	Immobilize in accepted waste form and store until MGR can receive	Immobilize in optimized waste form and dispose as HLW
"Fresh" Recycle FR Fuel	Not Applicable	Store & transport to ABTR	Store & transport to ABRs
Irradiated Recycle FR Fuel	Not Applicable	At-reactor storage for specified cooling period, transport & store for further cooling at AFCF, then process.	At-reactor storage for specified cooling period, then transport & store for further cooling at AFCF or fast SNF processing plant.
Unirradiated 'depleted' U	Store; later put in LLW disposable form and dispose	Storage for future disposition decisions including potential recycle or disposal as LLW	Storage for future disposition decisions including potential recycle or disposal as LLW
Low Level Waste	Transport to LLW facility	Transport to LLW facility	Transport to LLW facility
GTCC Waste	Not Applicable	Put in disposable form, store until GTCC facility is available, then transport for disposal	Put in disposable form, store until GTCC facility is available, then transport for disposal

Material T/S/D Requirements for Demonstration Facilities

The most urgent technical issues within GNEP are those needed to support early decisions. If it is decided to develop demonstration scale facilities, the technical support for critical decisions to proceed (such as CD-2 under major systems acquisition planning) could be needed within the next few years. Demonstration facilities under consideration for GNEP include an Engineering Scale Demonstration (ESD) of UREX+1a processing for LWR fuel, an Advanced Burner Test Reactor (ABTR) to develop and demonstrate a sodium cooled fast-spectrum reactor and fuel for actinide burning, and an Advanced Fuel Cycle Facility (AFCF) to produce and recycle actinide fuel for the ABTR. Under some schedules, there could be a decision point as early as 2008 whether to proceed with one or more of these facilities. A technically reasonable approach to manage all of the product and waste streams from these demonstration facilities will be one of many considerations that influence such a decision. While the lead-time for these TSD solutions is short, the magnitude of the material flows would be modest, and GNEP has access to both government and commercial material TSD capabilities. These existing capabilities may be adequate, or may be modified to become adequate with modest time and effort. This section outlines such approaches.

Demonstration Transportation Issues

Most transportation requirements for a GNEP demonstration phase may be met by use or extension of existing capabilities, either government or commercial. Some modification or expansion of capacity may be needed, along with material specific regulatory development.

Fuel Transportation

The ‘entry point’ for the advanced fuel cycle materials is transportation of spent LWR fuel to the ESD and AFCF. While SNF represents perhaps the largest transportation challenge due to very high radiation, significant heat generation and large physical size, casks for both truck and rail transport exist, along with the regulatory and transportation infrastructures needed. Both government and commercial transportation capability currently exits. Figure 3 is a NRC-certified rail cask.

Figure 3. NRC-certified Rail Transport Cask

The remaining issues primarily concern optimization, including standardization, scheduling and public perception regarding shipping SNF. Sufficient capacity is likely available for demonstration phase requirements, which are clearly small in comparison to the build-up needed for removal of SNF from utility storage. It is possible that this transport will be the responsibility of DOE OCRWM, where the standard contracts for receipt and disposition of SNF are held. If the ESD fuel input requirements are small, this transportation step may require definition of roles and responsibilities, but should not require any technical or capacity developments.

Fresh fuel for the ABTR will represent a new category of material transportation – physically smaller than LWR fuel, lower radiation levels and thermal output than LWR-SNF, but high enough to require remote handling, shielded transport and attention to heat removal. Existing spent fuel casks, including those for irradiated test and research reactor fuels, are more capable than needed, but are probably more readily qualified for this purpose than adding shielding and heat removal to fresh fuel shipping containers. Use of existing casks may be more cost effective at ABTR and ABR initial core scale than creating new casks optimized for this mission, if the careful handling requirements for fresh fuel can be accommodated. Nevertheless, during this time period the new casks optimized for ABR fuel must be designed, tested and licensed and procurement initiated. Also, issues related to safeguards and security during transport must be resolved, as current secure transport does not typically accommodate heavily shielded casks.

Spent ABTR fuel quantities will be dramatically less than the LWR-SNF quantities, with smaller physical size, but potentially very high radiation and thermal output. Existing research reactor spent fuel casks and transportation infrastructure should provide a good capability base, but there may be the need for some capacity addition and modification of casks, procedures and support infrastructure.

Separated Actinide Product Transportation

The mixed actinides extracted in UREX+1a for recycle in fast reactor fuel represent a new material transportation requirement. US national security programs have existing capability for the secure transport of Pu, but application of this to a commercial environment will likely pose a number of challenges. Packages for transport of Pu are available, but with limited ability to cope with the radiation and decay heat generated by the minor actinides. Similarly, there is capability to transport the minor actinides, but not in the quantities and mixtures represented by GNEP requirements. Modification and expansion of these capabilities, or the development of entirely new capability will be needed. Experience suggests that producing the needed equipment, procedures and supporting infrastructure will take time and resources, but this issue can readily be resolved in the time and scope of GNEP demonstration. It should be noted that co-location of the ESD and AFCF would reduce or eliminate this transportation requirement, and is being considered.

Waste Transportation

All materials destined for disposal will require transportation, but there has been extensive development of capability that can be applied, particularly at demonstration scale. Portions of this capability are commercial, portions are government, and additional technology is available in foreign programs that could be obtained.

High-level solidified wastes are technically the most challenging due to radiation and heat generation. Existing HLW transportation casks, procedures and support infrastructure should address much of the GNEP demonstration requirements. Modification of current systems may be required, such as modification of cask internal structure and re-certification for different waste loading, physical dimensions and thermal loading. Decisions on this must wait until GNEP waste forms are more fully defined, but should be readily achievable within GNEP schedules.

There may be unique requirements for separated waste streams that have not be transported in the past. Examples include separated Cs+Sr waste forms, Tc waste forms and gaseous radionuclides. While some of these have been transported extensively, such as Cs-137 in concentrated forms, the radionuclide mixtures, solidification forms and quantities are unique. Adaptation and/or expansion of existing transportation capability should be adequate for some of these waste forms, while others may require further development. Once these waste forms and transportation requirements are fully defined, such adaptation or development should be readily achievable within GNEP schedules.

Low-level radioactive waste transportation should not present significantly different challenges than current commercial and government LLW capabilities. GNEP demonstration LLW quantities should be moderate compared to current commercial LLW throughput.

Limited amounts of GTCC waste will be generated at GNEP facilities, but current government transportation capability for TRU waste from weapons programs is extensive and should cover the range of technical requirements. Expansion of this capability may be required, and can be accomplished on GNEP schedules. Licensing and regulatory review of the transportation system is already the responsibility of the NRC and is directly applicable to commercial endeavors.

Separated uranium represents a large mass and volume in a closed fuel cycle, but does not represent a large technical challenge. Procedures may require modification to address the higher activity of uranium separated from high burnup LWR fuels.

Demonstration Storage Issues

Most storage requirements for a GNEP demonstration phase may be met by use or extension of existing capabilities, either government or commercial. Some modification or expansion of capacity may be needed, along with material specific regulatory development. New facilities to be built should include sufficient on-site storage to meet requirements.

<u>Fuel Storage</u>

Interim storage of LWR SNF, fresh ABTR fuel and irradiated ABTR fuel will have to be provided. The interim storage of SNF is a well-developed technology, and both government and commercial expertise exists, as well as the infrastructure to build capacity as needed at the demonstration scale and schedule. DOE has proposed developing storage capacity for 40,000 MT of LWR SNF as part of the MGR program. Custom storage for ABTR fuel may require design and certification. Figure 4 shows an existing, NRC-certified dry SNF storage configuration.

<u>Figure 4. Existing NRC-certified SNF Dry Storage</u>

Separated Actinide Product Storage

It is likely that some mixed actinide product from ESD will require interim storage until the AFCF is able to accept it. While there is extensive experience in storage of Pu and minor actinides, there is no experience or existing capability for storing the Pu/minor actinide mixture in the quantities planned for GNEP demonstration. Existing Pu storage packages are not designed for the radiation and heat generation of the minor actinides. Modification and expansion of existing storage capabilities, or the development of entirely new capability will be needed. Experience suggests that producing the needed equipment, procedures and supporting infrastructure can readily be achieved in the time and scope of GNEP demonstration.

Waste Storage

Interim storage will be required for all waste streams. Extended storage is possible for select waste streams such as the potential long-term storage of Cs/Sr waste to allow for significant decay, or the extended storage of separated uranium awaiting future decision for reuse or disposal. Interim storage technology for most wastes exists in both government and commercial applications. A regulatory basis would be needed for long-term decay storage of Cs/Sr, but extended storage of both CsCl and SrF in large quantities has been carried out for decades. Development of methods and facilities may be required for unique wastes such as Tc and I bearing or gaseous waste forms, and for long-term decay storage. The extended storage of separated U may require extension of depleted U processes to account for the higher activity.

Demonstration Disposal Issues

Most disposal requirements for a GNEP demonstration phase may be met by use or extension of existing capabilities, either government or commercial. Some modification or expansion of capacity may be needed, along with material specific regulatory development.

Waste Disposal

Concern over disposal of additional radioactive wastes, and new types of waste, is a frequently expressed criticism of advanced fuel cycle proposals including GNEP. Residual wastes from past government and limited commercial reprocessing is cited as evidence of an “intractable” problem. A few background comments on this topic are in order. The importance of integrated waste management was not fully appreciated in the past. Prior processing was often performed with urgent national security or commercial priorities, with waste management deferred for ‘later’. Much has been learned, and commercial practice in other countries has evolved with major improvement in waste management. In addition, the GNEP technologies have been developed in AFCI and selected in large part on the basis of waste minimization and integration of waste management practice into all phases of operation. This can be seen in the potential division of wastes into different streams such as Cs/Sr, Tc, I, other HLW, clean U, etc primarily for the purpose of enabling optimized waste forms and disposal pathways that are not possible under the once-thru fuel cycle. Thus, the creation of new waste types represents improved waste management in the long term, not the creation of further burdens. Finally, as has been discussed in GNEP planning documents, the consumption of actinides as fast reactor fuel can provide tremendous improvements in HLW repository capacity and long-term performance. With this background, it is still important to consider each waste stream for confidence that an acceptable disposal pathway exists or can be reasonably developed.

Solidified HLW from fuel processing will be the most hazardous waste from GNEP demonstration facilities, and US law and policy dictates that it be disposed of in a deep geologic repository. It should be noted that this HLW would be disposed of in lieu of SNF that is processed instead of being disposed intact. The current US repository development program is tasked to dispose of both HLW and SNF, and the current repository design and safety analysis contains a mixture of the two. The modest scale of a GNEP demonstration phase would result in only a minor perturbation of the HLW/SNF mix in the repository. Therefore, if GNEP HLW fits within the design and performance parameter space of current HLW and SNF, they should be directly disposable in the repository in place of the SNF that has been processed. While more optimized waste forms may be desired at commercial scale, for demonstration scale it is probably most expedient to put HLW into forms already in the repository baseline. These include borosilicate glass for aqueous process wastes and metal alloy and glass-bonded zeolite waste forms for pyro-metallurgical process wastes. Because the radionuclide content and chemistry of the GNEP wastes will differ from the current wastes, these forms will require demonstration and testing to verify their performance. The processes for doing this are established, and given the separate management of the most problematic radionuclides (Cs, Sr, Tc, I, minor actinides), these forms should perform better than the currently acceptable forms.

The radionuclides that are proposed for separate management represent unique waste streams intended for disposal optimization, but requiring development of regulatory basis, waste form demonstration and disposal process implementation. Cs and Sr represent the primary short-term (30 year half life) sources of intense radiation and decay heat. Solidification forms such as bonded zeolites, mineral forms such as silicates or zirconolite/titanates, and glasses are potential candidates for geologic disposal. Incorporation of Tc into corrosion resistant metal alloys appears to offer the potential for a waste form with much better long-term retention that SNF, thus improving long-term repository performance. Iodine may be managed separately in a dilute mineral form to achieve improved long-term isolation, or combined with other wastes in glass or zeolites. If gaseous radionuclides are collected, they will require development of custom disposal methods such as long-lived gas cylinders (Kr) or solidification (H-3, C-14), but quantities are very small. Cladding hulls and assembly hardware can be consolidated into metal alloy waste forms, cemented, or potentially cleaned to LLW status.

The low-level radioactive wastes (LLW) from all the GNEP demonstration facilities should be manageable through existing commercial or government facilities. The quantities from the modest scale demonstration would represent a noticeable but not overwhelming perturbation on current LLW disposal facilities. UREX+1a is designed to minimize transuranic waste content beyond that disposable as LLW. Disposal of transuranic wastes is currently available to government defense related programs at the Waste Isolation Pilot Plant, and this provides insight into disposal of commercial GTCC wastes. There is no current commercial GTCC disposal capacity. Authorization of GNEP demonstration wastes for WIPP disposal is one possibility, although not likely, with storage until commercial capacity becomes available (like current industry practice) much more likely.

The uranium separated in UREX+1a is intended to qualify as low-level waste under current regulations. A portion of it may be used in ABTR fuel fabrication. It may also be stored for future reuse. If this uranium is to be discarded, the modest quantities from GNEP demonstration should permit disposal in either commercial or government LLW facilities.

Material T/S/D Requirements For Commercial Deployment

To support eventual decisions to deploy GNEP technologies at commercial scale, and to make commercialization practical, there will have to be confidence that radioactive materials can be transported, stored and disposed of in a timely an affordable manner. At deployment scale, large scale and sustainable solutions are required. Certain solutions that work at demonstration scale may not be adequate; regulations, facilities and methods may no longer be sufficient and new ones must be developed. In some areas existing capabilities may be adequate, or may be readily modified or expanded to become adequate. In some cases, solutions may simply benefit from re-optimization for large-scale application. This section considers these issues.

Deployment Transportation Issues

Most transportation requirements for a GNEP deployment may be met by expansion of existing commercial capabilities, or large-scale commercialization of current government operated capabilities. Some regulatory development may be needed.

Fuel Transportation

The largest transportation requirement in the GNEP fuel cycle materials is transportation of spent LWR fuel to the processing facility. SNF represents the largest transportation challenge due to very high radiation, significant heat generation and large physical size. While commercial SNF transport capacity currently exists the capacity is lacking for the scale of GNEP deployment. Development of additional commercial capacity within GNEP deployment schedules appears readily achievable. It is possible that this transport will be the responsibility of DOE OCRWM, where the standard contracts for receipt and disposition of SNF are held.

Fresh fuel for ABRs will represent a new category of material transportation – physically smaller than LWR fuel; with much lower radiation levels and thermal output than LWR-SNF, but high enough to require remote handling, shielded transport and attention to heat removal. Transport packages should have been designed, tested and licensed during the demonstration phase and procurement initiated. ABR SNF should be able to use LWR transportation casks with a new canister designed to meet ABR SNF requirements. The SNF payload, in terms of fuel mass, will be reduced, but in terms of the energy production from the fuel, it should be comparable to LWR SNF packages. The transportation infrastructure such as railroad, heavy haul rail cars and safety/security processes exist but will require expansion to meet deployment demands.

Separated Actinide Product Transportation

The mixed actinides extracted in UREX+1a for recycle in fast reactor fuel represent a new material transportation requirement. US national security programs have existing capability for the secure transport of Pu, but not with the radiation and decay heat generated by the minor actinides. There exists some capacity to transport the minor actinides, but not in the quantities and mixtures represented by GNEP requirements. Secure transport regulations, methods and infrastructure will have to be transitioned to commercial operation and expanded significantly in scale. A demonstration phase would offer opportunities for joint government/industry development of this commercial capacity. This transport activity is likely to be very closely scrutinized by non-regulatory government and media entities. Experience suggests that producing the needed regulations, equipment, procedures and supporting infrastructure will take time and resources, but can be accomplished within GNEP schedules. Co-location of fuel cycle facilities may reduce but probably cannot eliminate these transportation requirements.

Waste Transportation

All materials destined for disposal will require transportation, but there has been extensive development of capability that can be applied. Portions of the existing capability are commercial and can be scaled up, and portions are government operated and require commercialization. Additional technology is available in foreign programs that could be accessed if needed.

High-level solidified wastes are technically the most challenging due to radiation and heat generation. Existing HLW transportation casks, procedures and support infrastructure form a technology base to address GNEP deployment requirements. Capacity will have to be greatly expanded. Modification of current technology to optimize it for GNEP wastes may be required, such as modification of cask internal structure and re-certification for different waste loading, physical dimensions and thermal loading.

There may be unique requirements for separated waste streams that have not be transported in the past. Examples include separated Cs and Sr, Tc and gaseous radionuclide waste forms. While some of these have been transported extensively, such as Cs-137 in concentrated forms, the radionuclide mixtures, solidification forms and quantities are unique. Adaptation and/or expansion of existing transportation capability should be adequate for some of these waste forms, while others may require further development. Development of this capability commercially should be readily achievable within GNEP schedules. The regulatory basis may require redefinition to GNEP specific materials. If there is a demonstration phase, these waste forms and transportation requirements should be well defined prior to the deployment phase.

Low-level radioactive waste transportation should not present significantly different challenges than current commercial and government LLW capabilities. GNEP deployment LLW quantities may require eventual expansion of current commercial LLW capacity.

Limited GTCC waste will be generated at GNEP facilities. Current government transportation capability for TRU is extensive and applicable to commercial endeavors.

Separated uranium represents a large mass and volume in a closed fuel cycle, but does not represent a large technical challenge. Procedures may require modification to address the higher activity of uranium separated from high burnup LWR fuels.

Deployment Storage Issues

Storage requirements for commercial GNEP deployment can be met by expansion of current commercial technology and commercialization of existing government capabilities. Some modification or re-optimization of current methods may be needed, along with material specific regulatory development.

Fuel Storage

Interim storage of LWR SNF, fresh ABR fuel and irradiated ABR fuel will have to be provided. The interim storage of SNF is a well-developed technology, and significant commercial expertise exists, as well as the infrastructure to build additional capacity as deployment requirements expand. Custom storage for ABR fuel may require re-optimization from LWR designs and re-certification.

Separated Actinide Product Storage

It is likely that some of TRU product from separations will require short-term storage. Deployment of GNEP is limited by the availability of TRU and long-term storage is not anticipated. While there is extensive government experience in storage of Pu and minor actinides, commercial experience and capability for storing the Pu/minor actinide mixture in the quantities planned for GNEP deployment does not exist, and will require development. The regulatory framework for licensing storage facilities is in place and extensive technology development is not needed. If there is a demonstration phase, the needed equipment, procedures and supporting infrastructure will be defined, and deployment phase will only require commercial scale implementation.

Waste Storage

Interim storage will be required for all waste streams. Extended storage is possible for select waste streams such as the potential long-term storage of Cs/Sr waste to allow for significant decay, or the extended storage of separated uranium awaiting future decision for reuse or disposal. Interim storage technology for most wastes exists in both government and commercial applications but not at the scale needed for GNEP deployment. A new regulatory basis may be needed for long-term decay storage of Cs/Sr, but extended storage of both CsCl and SrF in large quantities has been carried out for decades. Development of methods and facilities may be required for unique wastes such as Tc and I bearing or gaseous waste forms, and for long-term decay storage. The extended storage of separated U may require extension of depleted U processes to account for the higher activity.

Deployment Disposal Issues

Initial disposal requirements for GNEP deployment may be met by use or extension of existing capabilities. Some current capabilities are government only facilities, and a commercial basis in regulation, design, certification and construction may be needed. Material specific regulations for unique waste streams may be needed. Eventually, expansion of capacity will be needed.

Waste Disposal

As discussed above in the Demonstration Disposal Issues section, concern over disposal of additional radioactive wastes, and new types of waste, is frequently expressed as a criticism of advanced fuel cycle proposals including GNEP. However, waste minimization and disposal optimization are two primary objectives of the technologies proposed. It is only at the commercial deployment scale that the intended waste management benefits of the closed fuel cycle can be realized.

Solidified HLW from fuel processing will be the most hazardous waste from GNEP facilities, and US law and policy dictates that it be disposed of in a deep geologic repository. It should be noted that this HLW will be disposed of in lieu of SNF that is processed instead of being disposed intact. The current US repository development program is tasked to dispose of both HLW and SNF, and the current repository design and safety analysis contains a mixture of the two. At large deployment scale a GNEP fuel cycle would result in a major perturbation of the HLW/SNF mix in the repository. If this occurs, then repository design may require re-optimization for processed wastes. In fact, much of the regulatory basis, design, operation and performance assessment of the repository may require re-examination. It is at this point that the waste management benefits of GNEP can be realized, with reduced actinides, lower long-term decay heat and waste forms optimized for specific problematic radionuclides. While a number of waste forms are currently included in the repository baseline, none are specifically optimized for GNEP type waste streams. Current waste forms such as: borosilicate glass for aqueous process wastes and metal alloy and glass-bonded zeolite waste forms for pyro-metallurgical process wastes serve as adequate 'default' waste forms until such time that re-optimized waste forms are developed. Because the radionuclide content and chemistry of the GNEP wastes will differ from the current wastes, these optimized forms will require demonstration and testing to verify their performance. The processes for developing and qualifying waste forms are established, and given the separate management of the most problematic radionuclides (Cs, Sr, Tc, I, minor actinides), these forms should perform better than the currently accepted forms.

The radionuclides that are proposed for separate management represent unique waste streams intended for disposal optimization, but requiring development of regulatory basis, waste form demonstration and disposal process implementation. Cs and Sr represent the primary short-term (30 year half life) sources of intense radiation and decay heat. Solidification forms such as bonded zeolites, mineral forms such as silicates or zirconolite/titanates, and glasses are potential candidates for geologic disposal. Incorporation of Tc into corrosion resistant metal alloys appears to offer the potential for a waste form with much better long-term retention that SNF, thus improving long-term repository performance. Iodine may be managed separately in a dilute mineral form to achieve improved long-term isolation, or combined with other wastes in glass or zeolites. If gaseous radionuclides are collected, they will require development of custom disposal methods such as long-lived gas cylinders (Kr) or solidification (H-3, C-14), but quantities are small. Cladding hulls and assembly hardware can be consolidated into metal alloy waste forms, cemented, or potentially cleaned to LLW status.

Initial low-level radioactive wastes (LLW) from all the GNEP deployment facilities should be manageable through existing commercial facilities. The quantities from the full-scale deployment would eventually exceed current LLW disposal capacities and will require expanded capacity. It should be noted that continued use of the once-thru fuel cycle will also eventually drive further LLW capacity. UREX+1a is designed to minimize transuranic waste content beyond that disposable as LLW. Disposal of transuranic wastes (TRU) is currently available to government defense related programs at the Waste Isolation Pilot Plant. There is no current commercial TRU disposal capacity. Authorization of GNEP demonstration wastes for WIPP disposal is one possibility, or interim storage until commercial capacity becomes available (this is current industry practice).

The uranium separated in UREX+1a is intended to qualify as low-level waste under current regulations. A portion of it may be used in ABR fuel fabrication. It may also be stored for future reuse. If this uranium is to be discarded, modest quantities could be disposed in commercial facilities. However, at large scale, a near surface LLW facility with large quantities of separated uranium is likely to fail EPA groundwater limits on total alpha contamination. It has been suggested that 'greater confinement disposal' could be developed commercially to meet this need, but a new regulatory basis would be required.

Material T/S/D issues for international deployment

The 'Global Partnership' of GNEP implies the potential for US commercial fuel cycle capability to serve foreign customers as part of the 'assured fuel services'. This has two primary impacts on transportation, storage and disposal issues. The first impact is the obvious potential for expanded capacity requirements throughout the fuel cycle. The second is the need for international agreement on regulations, methods, roles and responsibilities for nuclear material management.

Issues regarding international transportation of nuclear materials must be resolved through the IAEA and with affected nations. The requirements are similar (but not equal) to US requirements and, with some forethought; packages licensed in the US should be licensable for international traffic. Storage requirements for fresh fuel may be moderated as "just in time" delivery of fuel is suggested to reduce proliferation issues. On-site storage of SNF for a number of years for cooling is likely prior to transport. The transport of materials back to the US should not pose any major new technical issues, although cross-ocean transport of SNF and siting of receiving facilities will likely attract controversy. The GNEP concept implies that all fuel cycle wastes from US-provided fuels might be accommodated in this country.

Beyond identifying such impacts, and exploring potential solutions, in depth evaluation must await more complete definition of the GNEP international basis.

Statement of Conclusions

Demonstration and deployment of GNEP will introduce a number of new facilities and materials to the US nuclear industry over a period of almost 20 years. During that time R&D already begun and technology demonstrations currently being contemplated are expected to resolve issues associated with transportation, storage and disposal of the materials generated at those facilities. If there is a demonstration period, it is expected to provide for evolutionary solutions to be demonstrated and perfected so that at the time of commercialization the infrastructure is available to support deployment. During the R&D phase and parts of the demonstration phase, storage will be used to defer materials movements until needed for demonstration. Storage also allows an "undersized" facility to produce, over a period of time, materials for input to a facility with larger needs. For the greatest part, regulatory requirements for transportation, storage and disposal are reasonably stable and acceptable solutions can be developed with confidence. It is likely that the most intractable issues will have to do with provision of needed capacity for transportation, storage and disposal and with the possible need to change authorizing legislation for certain facilities.

In summary, while the GNEP fuel cycle creates new nuclear material transportation, storage and disposal requirements, it also simplifies many of the disposal issues. Near-term solutions at a demonstration scale either exist or can evolve from existing capabilities. Pathways and options for developing long-term commercial scale solutions should be readily achievable on GNEP time-schedules. While a demonstration phase would offer opportunities for development and demonstration of regulations, methods, facilities and experience for safe and effective nuclear material handling in a GNEP fuel cycle, proceeding directly to commercial deployment is possible with government/commercial partnership.

Appendix B

**A Survey of Potentially Useful Packages
for Storage, Transportation, and Disposition
of Un-irradiated, Irradiated, and Source Materials
for the Global Nuclear Energy Partnership (GNEP)**

Section 1. Introduction

The Global Nuclear Energy Partnership (GNEP)[iii] will require the use of Type A and Type B packages for the transportation and storage and disposition of nuclear materials and nuclear wastes.[iv] Many packages are currently certified by the Nuclear Regulatory Commission (NRC) under 10 CFR 71, Packaging and Transportation of Nuclear Material, for the transportation of un-irradiated and irradiated nuclear fuel in addition to specific separated fission products such as ^{90}Sr and ^{137}Cs. A number of these packages have been identified using the RAMPAC (Radioactive Material Packaging) Website [http://www.rampac.com/], maintained for EM-60's (Office of Safety Management and Operations) Packaging Certification Program by the Eagle Research Group for the Department of Energy (DOE). The Certificates of Compliance (CofC) and the Safety Evaluation Reports are both available on this Website. This status of NRC's CofC is effective as of August 3, 2007. The NRC Website is also available at http://www.nrc.gov/. A brief description of the GNEP fuel cycle is found in the following paragraph.

Spent Light Water Reactor (LWR) fuel will have to be shipped to the LWR Spent Nuclear Fuel Separation facility for separation using UREX-1A as a baseline technology. At present, this fuel is stored on site at many different utilities, producing commercial nuclear power, until it can be moved to a central long-term storage location such as the proposed Yucca Mountain facility in Nevada or processed as described in the GNEP fuel cycle. Isotopes such as ^{90}Sr and ^{137}Cs and uranium from the separation process will be sent to storage. Transuranics, including neptunium, plutonium, americium, curium, californium, etc., will be processed at the Transmutation Fuel Fabrication or Advanced Fuel Cycle Facility (AFCF) into feeder fuel for the Advanced Burner Reactor (ABR) (fast reactor). Initially, this will be an Advanced Burner Test Reactor (ABTR). Fresh fuel for the ABR or ABTR will necessitate remote handling, shielded transport, and heat removal due radiation levels and thermal output somewhat less than found for LWR spent nuclear fuel. Spent feeder fuel from the Advanced Burner Reactor will be shipped to the Transmutation Fuel Separation facility. Processing at the Transmutation Fuel Separation facility will generate fission products such as ^{90}Sr and ^{137}Cs, other fission products, and uranium. Other fission products include ^{85}Kr, ^{3}H, and ^{14}C. Solids such as cladding hulls and assembly hardware will also require disposition. Transuranics and uranium will go to the Transmutation Fuel Fabrication facility for production of more feeder fuel for the Advanced Burner Reactor completing the cyclic process. Inputs to the cyclic process include transuranics from the LWR Spent Nuclear Fuel Separation facility while the outputs are uranium, ^{90}Sr, ^{137}Cs, and other fission products. Co-location of the LWR Spent Nuclear Fuel Separation facility, Advanced Fuel Cycle Facility, Advanced Burner Test Reactor, and Transmutation Fuel Separation facility would minimize near term transportation requirements.

The GNEP fuel cycle is shown pictorially in Figure 1.

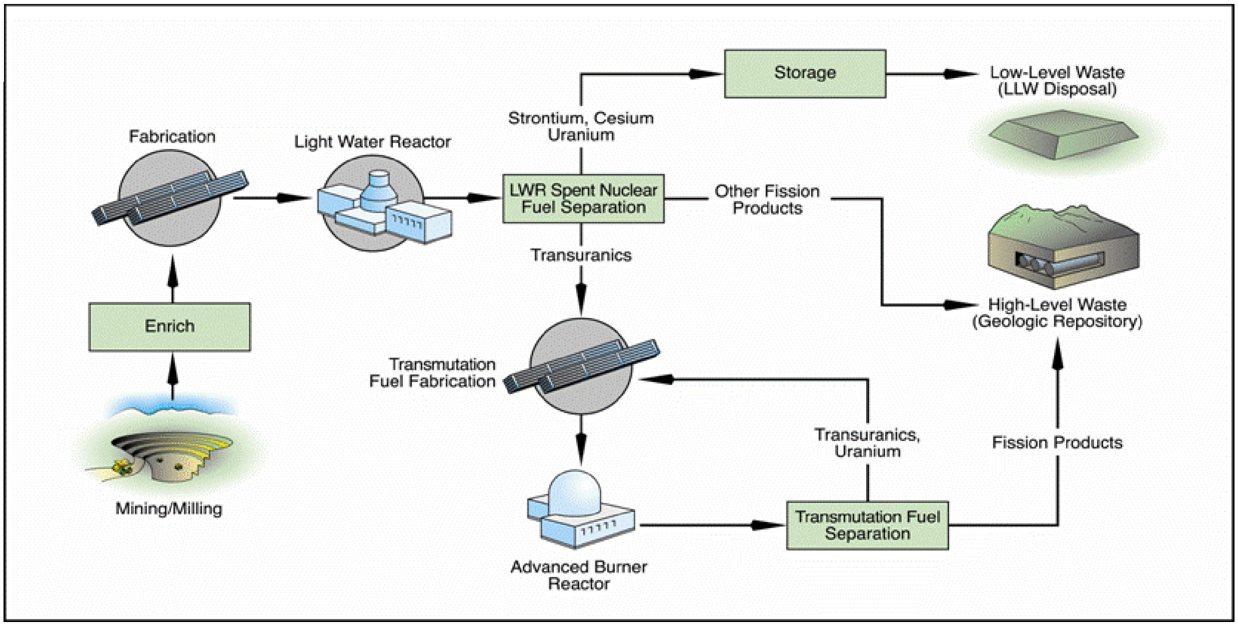

Figure 1. GNEP Fuel Cycle

Section 2. Packages for Transportation of Unirradiated, Irradiated, and Isotopic Materials.

Part 2A. Packages based on Nuclear Regulatory Commission Certificates of Compliance.
Sixty-eight (68) packages with Nuclear Regulatory Commission-approved Certificates of Compliance currently listed on the RAMPAC Website were examined for their characteristics to transport irradiated and un-irradiated nuclear materials and isotopes, for example, ^{90}Sr, ^{137}Cs, and ^{60}Co, where the first two are fission products arising from the separation process. For adding new or revised contents, the NRC typically issues a revision to its CofC. A total of 128 citations for NRC Certificates are currently listed on the RAMPAC Website. A number of the citations (14) are for letters of termination for packages. Others were deemed not relevant to GNEP. It is important to emphasize that the contents of the RAMPAC Website are fluid for the Certificates of Compliance.

A summary of packages for transportation of un-irradiated materials is given in Table I below. Information in the Table includes Certificate Number, Package Identification Number, Package Model Number, company or governmental organization to whom the Certificate is issued, and the expiration date for the Certificate. For the Packaging Certification Number, an example such as USA/9212/B(M)F-85, implies the Certificate is granted by the Nuclear Regulatory Commission for Certificate Number 9212, as a Type B Package for fissile material and develops a Maximum Normal Operating Pressure greater than 100 psig under the conditions of

10 CFR 71.71(c)(1) and that the package meets the regulatory requirements of the International Atomic Energy Agency (IAEA) for their 1985 standard.[v] Thirty-eight packages are described in the Table. The following packages have an expiration date on or before October 1, 2008: 814A, NNFD-10, 6400, and CNS 1-13C per 10 CFR 71.19(a)(3):

"A Type B package previously approved by the NRC, but not designated as B(U), B(M), B(U)F, or B(M)F in the identification number of the NRC CofC, or Type AF packages approved by the NRC prior to September 6, 1983, may be used under the general license of 71.17 with the following additional conditions: Paragraph (a) of this section expires October 1, 2008."[vi]

Most of the packages in the table are for transportation of uranium-based fuel although some pertain to mixed oxide fuels containing uranium and plutonium. An example of the latter is the MFFP Package for a Pressurized Water Reactor, based on the MK-BW/MOX 17x17 design. Packages are available for transport of fuel assemblies for Pressurized Water (PWR) and Boiling Water Reactors (BWR). For example, for the former, the Traveller STD and the Traveller XL Packages are available. The CE-B1 is available for the latter reactor type. The 6400 Package can be used for ^{233}U oxide and thorium oxide fuel rods for a Light Water Breeder Reactor (LWBR). The Model 1500 Package can be used for the transportation of $^{90}SrF_2$ and $^{137}CsCl$ capsules.

An EXCEL database is additionally available with more detailed information providing a summary of each Certificate. The EXCEL data base includes, in addition to the information presented here, a listing of the fuel components, isotopes, uranium enrichment, mass limits for uranium, decay heat, cooling time for spent fuel, and activity where appropriate. Reference to the specific Certificate and respective Safety Analysis Report (SAR) for the package will allow for access to the details. The NRC prefers the term Safety Analysis Report while the Department of Energy uses instead Safety Analysis Report for Packaging (SARP).

Table I. Selected Nuclear Regulatory Commission Certificates of Compliance for Radioactive Material Packages				
Packages for **Un-irradiated** Materials				
Certificate Number	Package Identification Number	Model Number	Issued to	Expiration Date
4986	USA/4986/AF	RA-3	Global Nuclear Fuel-Americas	March 31, 2008
5149	USA/5149/B( )F	814A	BWX Technologies, Inc.	October 1, 2008
5086	USA/5086/B(U)F	UNC-2600	BWXT, Nuclear Products Division	February 28, 2009
5797	USA/5797/B(U)F	Inner HFIR Outer HFIR	DOE	September 30, 2007
6078	USA/6078/AF	927A1 927C1	Westinghouse Electric Company	October 1, 2008
Table I. Packages for **Un-irradiated** Materials (Continued)				
Certificate Number	Package Identification Number	Model Number	Issued to	Expiration Date
6206	USA/6206/AF	Model B	Framatome ANP, Inc.	October 1, 2008
6347	USA/6347/AF	FSV-3	General Atomics	September 30, 2007
6357	USA/6357/AF	NNFD-10	BMX Technologies, Inc	October 1, 2008
6400	USA/6400/B( )F	6400	Westinghouse Electric Company	November 30, 2007
6581	USA/6581/AF	51032-1	Framatome ANP, Inc.	October 1, 2008
9034	USA/9034/AF	TRIGA-I	General Atomics	December 31, 2010
9037	USA/9037/AF	TRIGA-II	General Atomics	December 31, 2010
9081	USA/9081/B( )	CNS 1-13C	Duratek	January 31, 2008
9099	USA/9099/B( )F-85	ATR	DOE	January 31, 2009
9168	USA/9168/B(U)	CNS 8-120B	Duratek	June 30, 2010
9203	USA/9203/AF	DHTF	Framatome ANP, Inc.	February 28, 2011
9204	USA/9204/B(U)-85	CNS 10-160B	Duratek	October 31, 2010
9212	USA/9212/B(M)-85	RH-TRU-72-B	DOE	February 28, 2010
9217	USA/9217/AF	ANF-250	Framatome ANP Richland, Inc.	June 30, 2010
9239	USA/9239/AF	MCC-3, MCC-4, MCC-5	Westinghouse Electric Company	March 31, 2012
9248	USA/9248/AF	SP-1, SP-2, SP-3	Framatome ANP, Inc.	February 28, 2009
9250	USA/9250/B(U)-85	5X22	BWX Technologies	March 31, 2008
9251	USA/9251/AF	BW-2901	Framatome ANP, Inc.	October 31, 2007
9252	USA/9252/AF	51032-2	Framatome ANP, Inc.	October 31, 2008
9272	USA/9272/AF-85	CE-B1	Westinghouse Electric Company, LLC	January 31, 2007
9274	USA/9274/AF	ABB-2901	Westinghouse Electric Company, LLC	September 30, 2007

Table I. Packages for **Un-irradiated** Materials (Continued)				
Certificate Number	Package Identification Number	Model Number	Issued to	Expiration Date
9285	USA/9285/AF-85	SRP-1	Global Nuclear Fuel-Americas, LLC	October 31, 2007
9288	USA/9288/B(U)F-96	CHT-OP-TU	Columbiana Hi Tech, LLC	March 31, 2010
9289	USA/9289/B(U)F-85	WE-1	Framatome ANP, Inc.	February 28, 2009
9291	USA/9291/B(U)F-96	Liqui-Rad (LR) Transport Unit Package	Columbiana Hi Tech, LLC	October 31, 2011
9292	USA/9292/AF-85	PATRIOT	Westinghouse Electric Company, LLC	August 31, 2010
9294	USA/9294/AF-85	NPC	Global Nuclear Fuel-Americas, LLC	November 30, 2010
9295	USA/9295/B(U)F-96	MFFP	Packaging Technology, Inc.	June 30, 2010
9297	USA/9297/AF-96	Traveller STD and Traveller XL	Westinghouse Electric Company	March 15, 2010
9301	USA/9301/AF-85	TNF-XI	Packaging Technology, Inc.	August 30, 2008
9309	USA/9309/B(U)F-96	RAJ-II	Global Nuclear Fuel-Americas, LLC	November 30, 2009
9315	USA/9315/B(U)F-96	ES-3100	DOE	April 30, 2011
9328	USA/9328/AF-96	TN-55	Packaging Technology, Inc.	April 30, 2012

Table II below gives a summary of packages for transportation of irradiated materials. An asterisk indicates the Certificate is not renewable by NRC. Twenty-four packages are described in the Table. The following packages have an expiration date on or before October 1, 2008: T-2, GE-100, 1500, BMI-1, FSV-1, Unit3, NLI-1/2, TN-8 and TN-8L, and CNS 1-13G per 10 CFR 71.19(a)(3) as described above in the section under packages for un-irradiated materials. The T-2 Package can transport irradiated clad fuel as solid metal, oxides, nitrides, and carbides of uranium, plutonium, or mixed uranium and plutonium. The following packages have the capability to transport PWR and BWR spent fuel: IF-300, NLI-1/2, TN-8/TN-8L, NLI-10/24, NAC-LWT, HI-STAR 100 System, UMS Universal Transport Cask, and the Fuel Solutions TS 125 Transportation Package.

Table II. Selected Nuclear Regulatory Commission Certificates of Compliance for Radioactive Material Packages				
Packages for **Irradiated** Materials				
Certificate Number	Package Identification Number	Model Number	Issued to	Expiration Date
5607	USA/5607/B( )F	T-2	DOE	October 1, 2008
5926	USA/5926/B( )F	GE-100	General Electric Company	May 31, 2008
5939	USA/5939/B( )F	1500	General Electric Company	October 1, 2008
5957	USA/5957/B( )F	BMI-1	DOE	October 1, 2008
9001*	USA/9001/B( )F	IF-300	Duratek	October 1, 2008
9010*	USA/9010/B( )F	NLI-1/2	NAC International, Inc.	October 1, 2008
9015	USA/9015/B( )F	TN-8 TN-8L	Transnuclear, Inc.	October 1, 2008
9016	USA/9016/B( )F	TN-9	Transnuclear, Inc.	October 1, 2008
9023	USA/9023/B( )F	NLI-10/24	NAC International, Inc.	July 31, 2008
9200	USA/9200/B(M)F	125-B	DOE	June 30, 2011
9216	USA/9216/B( )F	CNS 1-13G	Duratek	January 31, 2008
9225	USA/9225/B(U)-96	NAC-LWT	NAC International, Inc.	February 28, 2010
9226	USA/9226/B(U)F-85	GA-4	General Atomics	October 31, 2008
9228	USA/9228/B(U)F-96	2000	General Electric Company	May 31, 2011
9233	USA/9233/B(U)	TN-RAM	Transnuclear, Inc.	April 30, 2010
9235	USA/9235/B(U)F-96	NAC-STC	NAC International, Inc.	March 31, 2009
9253	USA/9253/B(U)-85	TN-FSV	DOE	May 31, 2009
9255	USA/9255/B(U)F-85	NUHOMS MP187 Multi-Purpose Cask	Transnuclear, Inc.	October 31, 2008
9261	USA/9261/B(U)-85	HI-STAR 100 System	Holtec International	March 31, 2009
9270	USA/9270/B(U)-96	UMS Universal Transport Cask Package	NAC International, Inc.	October 31, 2007
9276	USA/9276/B(U)-85	TS125 Transportation Package	BNFL Fuel Solutions	September 30, 2007
Table II. Packages for **Irradiated** Materials (Continued)				
Certificate Number	Package Identification Number	Model Number	Issue to	Expiration Date
9277*	USA/9277/B( )F	FSV-1 Unit 3	General Atomics	October 1, 2008
9293	USA/9293/B(U)F-85	TN-68 Transport Package	Transnuclear, Inc.	February 28, 2011
9302	USA/9302/B(U)-85	NUHOMS-MP197	Transnuclear, Inc.	July 31, 2007

Table III below summarizes packages for transportation of isotopes such as ^{90}Sr and ^{137}Cs as well as ^{60}Co. The isotopes are either present as special form material or doubly encapsulated. For example The Model Sentinel-25 series can accommodate up to 125,000 curies (Ci) of ^{90}Sr as its titanate or fluoride compounds as special form radioactive material. The 1500 Package can accommodate up to 458,000 Ci $^{90}SrF_2$ or $^{137}CsCl$ in capsule form. Certificate Numbers 4888, 5939, and 5984 expire on or before October 1, 2008 per 10 CFR 71.19(a)(3) as described in the section pertaining to packages for un-irradiated materials. Model Numbers RG-1 and 1500 are for doubly encapsulated isotopes while the other Models are special form. One of the contents for the Model 1500 is in special form. The Model 1500 also appears in Table II.

Table III. Selected Nuclear Regulatory Commission Certificates of Compliance for Radioactive Material Packages				
Packages for **Isotopes as Special Form** or **Doubly Encapsulated** Materials				
Certificate Number	Package Identification Number	Model Number	Issued to	Expiration Date
4888	USA/4888/B( )	Sentinel-25A, LCG-25A;Sentinel-25B,LCG-25B;Sentinel-25C,LCG-25C;Sentinel-25C3,-25D,-25E,-25F	Department of the Air Force	October 1, 2008
5862	USA/5862/B( )	Sentinel-100F	Department of the Air Force	October 1, 2008
5939	USA/5939/B( )F	1500	General Electric Company	October 1, 2008
5984	USA/5984/B( )	5984	J.L. Shepard & Associates	August 31, 2007

Table III. Packages for **Isotopes as Special Form** or **Doubly Encapsulated** Materials (Continued)				
Certificate Number	Package Identification Number	Model Number	Issued to	Expiration Date
6703*	USA/6703/B( )	RG-1	General Atomics	September 30, 2008
6786*	USA/6786/B( )	URIPS-8A URIPS-8B	Department of the Navy	October 1, 2008
9030*	USA/9030/B( )	MW-3000 Sentinel-8	Department of the Navy	October 1, 2008
*Indicates Certificate not renewable by NRC				

Part 2B. Packages based on Department of Transportation Competent Authority Certificates.

Another area, covered by the RAMPAC Website, is issuance of Competent Authority Certification for packages by the United States Department of Transportation (DOT) Pipeline and Hazardous Materials Safety Administration or the DOT Research and Special Programs Administration such that IAEA Regulations for the Safe Transport of Radioactive Material and DOT 49 CFR 100-199[vii] are adhered to by the applicant and user. The package design is “approved for use within the United States for import and export shipments only.” Some three hundred and one (301) certificates are available on the RAMPAC Website as DOT-IAEA. Many of the entries pertain to transportation of isotopes particularly for medical or laboratory applications. In a number of instances, NRC Certificates of Compliance are appended to the DOT Competent Authority Certification. About seventeen of the Competent Authority Certifications examined here overlap with NRC CofC, discussed previously, and have relevance to transportation of un-irradiated, irradiated, and isotopic materials as part of GNEP. The Packages include RAJ-II (revalidation of Japanese Competent Authority), RAJ-II (with NRC CofC appended), RA-3, 51032-1 (DOT Research and Special Programs Administration), TRIGA-I, TRIGA-II, NAC-LWT, 2000, MCC-3, MCC-4, and MCC-5, SP-1, SP-2, and SP-3 (DOT Research and Special Programs Administration), 5X22, ABB-2901, SRP-1 (DOT Research and Special Programs Administration), PATRIOT, NPC, Traveller STD and Traveller XL, TNF-XI, and ES-3100. These packages do not have the restriction of “approved for use within the United States for import and export shipments only.” since they were previously reviewed by the NRC for domestic use.

Thirty (30) Competent Authority Certifications, evaluated here, are revalidation of competent authority for other nations including the United Kingdom, Canada, Japan, France, and Germany. Documentation such as a Competent Authority Certification is necessary for each nation the package must pass through from point of origin to destination. The Competent Authority Certifications examined here are those potentially relevant to GNEP. They are enumerated in Table IV. Ten of the packages are for irradiated materials while thirteen are for transportation of isotopes, in some instances as special form materials. One package for irradiated materials (JMS-87Y-18.5T) appears three times as the approved contents vary among the Certificate Numbers. The 7N-2 package appears twice but for different irradiated contents in each case. The AECL-CRL Irradiated Material Transportation Package can be used for shipment of spent CANDU fuel. The Croft Associates Model 2773A (SAFSHIELD) can transport up to 1,180 g ^{137}Cs in special form. The MDS Nordion F-168 and F-168-X is allowed 1×10^5 Ci of ^{137}Cs in special form (similar to the SAFSHIELD). Even though the latter application is for use as a source, it gives an idea of the magnitude of ^{137}Cs allowed for shipments.

Table IV. Selected United States Department of Transportation Competent Authority Certification for Radioactive Material Packages

Certificate Number (USA)	Package Identification Number	Model Number	Issued to	Expiration Date
0208**	USA/0208/B(U)F-96 J/61/B(U)F-96	JRC-80Y-20T	Japan	September 8, 2008
0337***	USA/0337/B(U)-96 GB/2773A/B(U)-96	Croft Associates 2773A (SAFSHIELD)	United Kingdom	December 31, 2009
0371**	USA/0371/B(U)F-85 D/4160/B(U)-85	TN 7-2 Transport Package	Germany	December 31, 2008
0382***	USA/0382/B(U)-96 GB/2835A/B(U)-96	Croft Associates 2835A	United Kingdom	July 31, 2012
0401**	USA/0401/B(U)F-96 J/111/B(U)F-96	JMS-87Y-18.5T	Japan	October 12, 2009
0452**	USA/0452/B(U)F-96 J/119/B(U)F-96	JRF-90Y-950K	Japan	October 12, 2009
0453*&***	USA/0453/S	6810/143-512	IAEA Certificate of	September 30, 2009

			Competent Authority for J.L. Shepherd & Associates	
0460	USA/0460/AF-96 D/4306/AF-96	RA-3D	Germany	July 31, 2008
0464*&***	USA/0464/S	6810-190	IAEA Certificate of Competent Authority for J.L. Shepherd & Associates	September 30, 2009
0485	USA/0485/B(U)F CDN/4212/B(U)F	4H (Serial Numbers 1 to 8)	Canada	April 30, 2009
0490	USA/0490/AF-96 J/37/AF-96	NT-IV	Japan	May 25, 2009
0542	USA/0542/AF-96 J/134/AF-96	NFI-V	Japan	January 16, 2009

Table IV (Continued)				
Certificate Number (USA)	Package Identification Number	Model Number	Issued to	Expiration Date
0545***	USA/0545/B(U)-96 GB/3605C/B(U)-96	3605C (multiple isotopes)	United Kingdom	September 30, 2007
0551**	USA/0551/B(U)F-85 D/4326/B(U)F-85	GNS-16	Germany	November 23, 2008
0553**	USA/0553/B(U)F-85 CDN/2061/B(U)F-85	Irradiated Material Transportation Package	Canada	May 31, 2010
0558**	USA/0558/B(U)F-96 J/150/B(U)F-96	JMS-87Y-18.5T (Kyoto University)	Japan	October 31, 2009
0573**	USA/0573/B(U)F-85 D/4342/B(U)F-85	TN 7-2 Irradiated Fuel Assembly Cask	Germany	December 31, 2008
0587*&***	USA/0587/B(U)-85 CDN/2067/B(U)-85	MDS Nordion Gammacell 40MK3 Irradiator (Serial Numbers 11 and Subsequent)	Canada	February 29, 2008
0595	USA/0595/AF-96 J/156/AF-96	RAJ-III (1996)	Japan	May 31, 2008
0617***	USA/0617/B(U)-96 CDN/2081/B(U)-96	MDS Nordion F-168 (Serial Numbers 53-76 & 83-up) F-168-X [1996] (Serial Numbers 77-X, & up)	Canada	November 30, 2007
0629*&***	USA/0629/S	X.14 & X14/1 (^{241}Am)	IAEA Certificate of Competent Authority for AEA Technology QSA, Inc.	July 31, 2008
0653	USA/0653/AF-96 F/381/AF-96	TNF-XI	France	December 31, 2011
0665***	USA/0665/B(U)-96 CDN/2083/B(U)-96	MDS Nordion F431/GC-1000 F431/GC-3000	Canada	November 30, 2007

Table IV (Continued)				
Certificate Number (USA)	Package Identification Number	Model Number	Issued to	Expiration Date
0674***	USA/0674/B(U)-96 CDN/2076/B(U)-96	MDS Nordion Model No. F-430/GC-40, F-430/GC-1000 & GC-3000, F-430/CIS Model IBL 437C, F430/CIS Model IBL 637, F-430/Molsgaard Model GC-2000	Canada	February 28, 2011
0696***	USA/0696/S-96	QSA Global Inc. Model II Source Capsule (multiple isotopes)	IAEA Certificate of Competent Authority for QSA Global, Inc.	February 28, 2011
0713**	USA/0713/B(U)F-96 J/166/B(U)F-96	JMS-87Y-18.5T (Musashi Institute)	Japan	March 16, 2008
0742**	USA/0742/B(U)F-96 J/167/B(U)-96	JRF-90Y-950K	Japan	July 20, 2008
0745	USA/0745/AF-96 D/4365/AF-96	ANF-50	Germany	January 1, 2008
6217*&***	USA/6217/B(U) CDN/2003/B(U)	MDS Nordion F-143 Transfer Case, Serial Numbers 20, 50, 53, 54, 59, 62 & 64 F-158 Transfer Case, Serial Numbers 3-6, 8-10 & 14	Canada	March 31, 2008
6355***	USA/6355/B(U) CDN/2009/B(U)	MDS Nordion F-147 Transfer Case, Serial Numbers 18, 24, 26, 27, 34-36, 39-48, 50, 52, 54, 56-60	Canada	November 30, 2010

Table IV (Continued)
*Approved by DOT Research and Special Programs Administration **Packages for Irradiated Materials ***Packages for Isotopes

An EXCEL database, separate from the one discussed above in Part 2A, is additionally available with more detailed information providing a summary of each Competent Authority Certification. The EXCEL data base includes, in addition to the information presented here, a listing of the fuel components, isotopes, uranium enrichment, mass limits for uranium, decay heat, cooling time for spent fuel, and activity where appropriate. Reference to the specific Certificate and respective

Safety Analysis Report or Safety Analysis Report for Packaging for the package will allow for access to the details.

Section 3. Conclusions

Some of the packages, approved by the NRC with Certificates of Compliance, certainly have viability for short-term demonstration of GNEP where facilities are co-located. However, for long-term demonstration of GNEP where other than domestic shipments are required, packages are needed for transportation of large activities of transuranic elements in addition to plutonium. The presence of transuranic elements will create new contents and shielding issues that, at the very minimum, will lead to a review and revision of the SAR or SARP if not outright design of new packages to accommodate higher photon and neutron radiation fluxes from feeder fuel going to the ABTR or ABR. Storage of nuclear materials in packages, designed for transportation, is currently a contentious issue for packages certified by EM-60's Packaging Certification Program for the Department of Energy. Over time, flammable gas concentrations will increase and radiation damage to primary containment boundary components such as O-rings will accumulate. Also, the issue of yearly maintenance to the DOE-certified packages currently in use for storage of nuclear materials requires resolution. The Model 9975 Package in use at Savannah River National Laboratory is one example of a transportation package accommodating storage of nuclear materials.

References

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[i] GNEP—Basis Document, *Integrated Strategy for Nuclear Material Transportation, Storage, and Disposal Strategy Under the Global Nuclear Energy Partnership*, Review Draft 2—October 4, 2006. See Appendix A of this report.

[ii] *Transportation and Storage Regulations Applicable to the GNEP*, Richard H. Yoshimura, Paul McConnell, Ken B. Sorenson, Sandia National Laboratory, January 31, 2007.

[iii] GNEP—Basis Document, *Integrated Strategy for Nuclear Material Transportation, Storage, and Disposal Strategy Under the Global Nuclear Energy Partnership*, Review Draft 2—October 4, 2006. See Appendix A of this report.

[iv] *Transportation and Storage Regulations Applicable to the GNEP*, Richard H. Yoshimura, Paul McConnell, Ken B. Sorenson, Sandia National Laboratory, January 31, 2007.

[v] *Regulations for the Safe Transport of Radioactive Material—2005 Edition—Safety Requirements*, IAEA Safety Standards Series No. TS-R-1, International Atomic Energy Agency, Vienna, Austria (April 2005).

[vi] *Packaging and Transportation of Radioactive Material*, Code of Federal Regulations, Title 10, Part 71, Washington, DC (December 2006).

[vii] Title 49, Code of Federal Regulations, Parts 100–199, United States of America, Washington, DC (October 1, 2006).